# A HOLOGRAPHIC ARRAY FOR IONOSPHERIC LIGHTNING (HAIL) RESEARCH

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## LONG-TERM GOAL

Completion of a system using VLF remote sensing to map ionospheric changes due to lightning induced disturbances. This system, covering much of North America, will run in real time and provide two-dimensional ionospheric profile information on the web.

## SCIENTIFIC OBJECTIVES

Recently, VLF remote sensing has emerged as a powerful tool for the imaging of ionospheric disturbances. In particular, the strip holography technique (e.g., Chen, et al., Radio Science, vol. 31, p.335, 1996) is a method by which the relative amplitude and phase changes at a series of VLF receivers are combined to yield a volumetric profile of the scattering region. Previous studies have been done for certain cases where a storm happened to pass through the junction between two transmitter-receiver paths, but the strip holography simulation supposed that an array of appropriately spaced receivers would be able to image disturbances over a wider range of land area. With this array now operating in the field, these past techniques and models will be applied towards the new data in the hope of improving the understanding of the occurrence distribution and characteristics of ionospheric disturbances, working toward a system which will be able to image these disturbances in near real-time.

By deploying appropriately spaced receivers (see Figure 1), the area above midwestern storms is covered with a fine grid to estimate the scattered electromagnetic field due to a locoized ionospheric disturbance. These scattered field estimates are then compared with magnitude and phase change of an ionospheric scattering region. VLF strip holography has been shown to determine the horizontal extent and shape of the D-region disturbance using a three-dimensional numerical model of VLF propagation in the Earth-ionosphere waveguide

## APPROACH

The strip holography inversion requires that the receivers be placed approximately 100km apart in order to image the disturbances. Once in place, a robust hardware and software package enables sensitive measurements of amplitude and phase, and then stores these measurements on tape or transmitts them back to Stanford over the Internet. At Stanford, data archives on CDROM preserve the high resolution data while low resolution data remains available on the HAIL website.

# Report Documentation Page

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## WORK COMPLETED

During the Spring and summer of 1997, the HAIL group completed the following project tasks:

1. Development of new 16 bit data acquisition interface;
2. Construction of appropriate front end electronics for signal conditioning;
3. Integration of GPS timing information into data acquisition for precise timing and phase reference;
4. Development of LMS algorithm for time domain phase estimation;
5. Incorporation of the above algorithms into realtime user friendly software;
6. Design and competion of custom ftp client for data transmission;
7. Web server set up to make data available to the public;
8. Educational hyperlinked science essays with animations and a custom Java data browser for interaction with high school students;
9. Custom Matlab library written for high resolution data analysis;
10. Five sets of electronics and data acquisition systems built and deployed; and
11. Ongoing data analysis and CDROM archiving.

An overview of the new Narrowband receiver is shown in Figure 2.

## RESULTS

Numerous VLF events are now measured weekly, in both amplitude and phase, at all the deployed sites. Using the high resolution data, we have identified both early/fast and LEP events. The size of the events appears to be consistant with predicted scattering patterns. However, the resulting data shows that Trimpi events occur with a much higher rate than previously observed. Because of the variation in event size across the array (from an event only at one station, to an event of the same size at all 5 stations), the 100km array spacing estimate appears to confirm the expected lateral extent of the dirstubance. For the first time, a linear array of receivers shows examples of constructive and destructive interference sampled at the right spacing. The data from the array is now being used to more carefully determine the size and profile of the disturbed ionosphericprofile.

## IMPACT/APPLICATION

A major application of the HAIL project is to use simultaneous high resolution measurements of VLF subionospheric signals at the receivers to assess the spatial distribution of ionoshperic disturbances in real time. The HAIL digital receiver can be easily integrated with several software models to provide real time information about the ionosphere. For example, the next goal is to integrate the HAIL software with the multiple mode three dimensional model of VLF propagation in the earth-ionosphere waveguide in the presence of localised D region disturbances, to provide a real time two dimensional ionospheric profile over much of North America. Another application is to use the VLF amplitude and phase measurements made by HAIL digital receivers stationed over North America, to determine the position of auroral electrojet in real time. The HAIL receiver has enabled precise recording of a large number of events associated with ionospheric disturbances due to lightning discharges, with maximum signal to noise ratio, made possible by better signal processing techniques and better front-end electronics.

## TRANSITIONS

The HAIL software will be used in a project for monitoring the Auroral Electrojet. All future narrowband receivers are planned to upgrade to this more sensitive digital demodulation. In addition, the front-end electronics will also be used as a part of the future systems. An extension for the hardware which will be capable of storing the broadband VLF directly, is currently in the design phase.

Since our acquisition takes place during the night time, during the day high school students utilize the Pentium 200MHz computers to look at the data on the Internet.

## RELATED PROJECTS

"Characterizationn of the Auroral Electrojet and the Ambientand Modified D-Region for HAARP Using Long-Path VLF Diagnostics"

"Global Thurnderstorm Activity and Its Effects on the Radiation Belts and the Lower Ionosphere"

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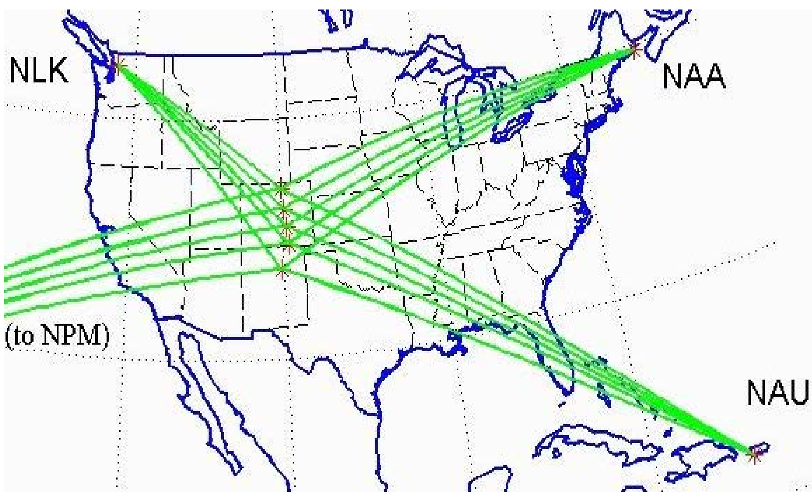


Figure 1. Deploying Appropriately Spaced Receivers

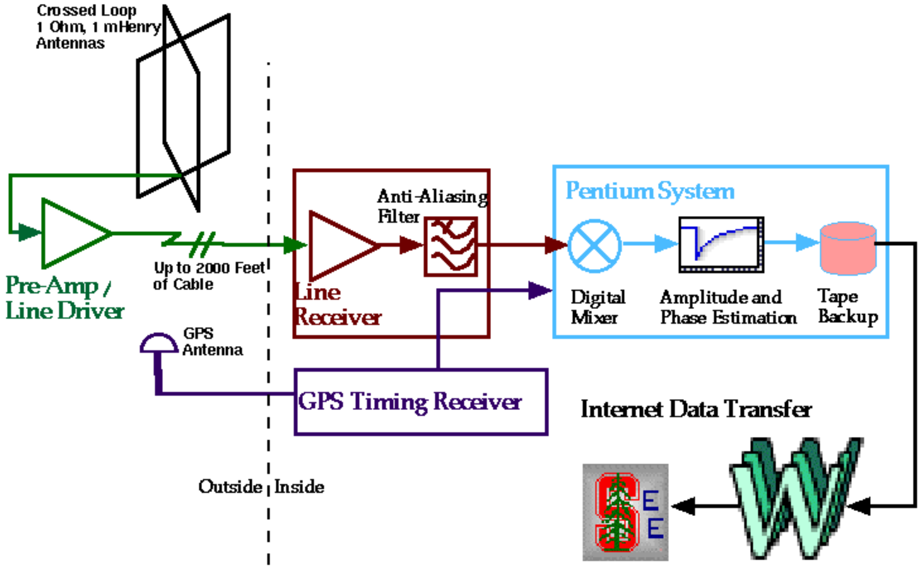


Figure 2. New Narrowband Receiver